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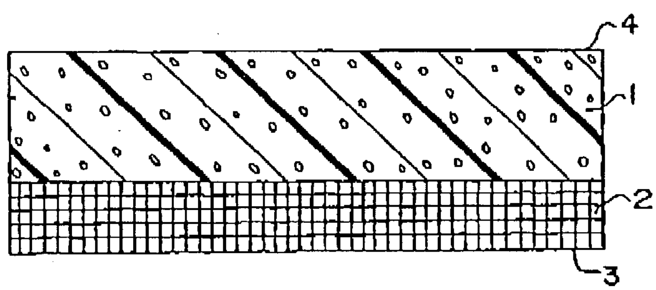

(57) Abstract

A thermally conductive interface material formed of a polymeric binder (2), one or more thermally conductive fillers (1) and an expanded metal mesh layer (3) at least partially embedded into one of the major surfaces of the binder is disclosed. Preferably, the interface is a pressure sensitive adhesive material and more preferably, it is in the form of a tape or self-adhesive pads.

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CONFORMAL THERMALLY CONDUCTIVE INTERFACE MATERIAL

The present invention relates to a thermally conductive interface material for transferring thermal energy from a heat source to a heat sink. More particularly, the present invention relates to a thermally conductive material which is conformable, providing for better and more uniform contact between the thermally conductive material and the substrates to which it is bonded.

BACKGROUND OF THE INVENTION

The present invention relates to a thermally conductive interface material that is interposed between a source of heat, such as an electronic component and a heat sink. The most common example of this invention is the use of a thermal material between a semiconductor device and a heat sink so that heat generated by the semiconductor can be removed.

Typically, silicone, thermoplastic rubber acrylic or urethane binders filled with one or more thermally conductive materials are used as the thermal interface. One such product is commercially known as CHO-THERM® thermally conductive materials, available from Chomerics, Inc. and is a silicone or urethane binder filled with alumina or boron nitride filler.

In placing the thermally conductive material between the heatsource and the heatsink, care must be taken to ensure that there is a good mating between the thermally conductive material and the adjacent substrate. Often one of the substrates will have disconformity in its mating surface, such as a high spot or low spot caused by manufacturing, or a slight twist, bend or tilt caused by handling, shipping or application. This leaves a spot or area which is not mated directly to the thermal interface material and thus is exposed to the air. Air is a notoriously poor conductor of heat and its presence reduces the ability of the thermally conductive material to transport heat from its source to its sink. This can lead to an overheating of the heat source.

U.S. Patent 4,654,754 disclosed two means for overcoming the problem. The first is to use a series of metal springs or thermal links which apply a counterpressure to the adjoining substrate in response to the pressure applied. The second is to use a dimpled thermal pad such that the dimples compress or move in relation to the pressure applied by the adjoining substrate. Both act to conform to irregular spacing between the substrates. Both however, are specifically designed modifications which are expensive to manufacture and use and which do not address the ability to provide constant and uniform thermal conductivity across the entire substrate surface.

Therefore, there is a need for a thermally conductive material that will minimize the problem of disconformity trapped between the thermal material and the adjacent substrate.

OBJECTS AND SUMMARY OF THE INVENTION

The present invention provides a thermally conductive material which contains a means for conforming to the surfaces between the thermally conductive material and the substrates between which it is interposed. The means for conforming is an expanded metal mesh preferably encased within both major surfaces of the thermally conductive material so that as pressure is applied between the thermally conductive material and the adjacent heat sink or heat source, the thermal material conforms to the space between the two adjacent surfaces.

Further, the present invention provides a conformal thermal interface material formed of a polymeric binder, a thermal filler and which contains a layer of expanded metal mesh. The expanded metal mesh deforms, even under relatively low pressures, so as to conform to the shape of the surfaces between which it is applied. This allows the material to minimize air gaps without the need for constant pressure between the layers. This is unlike the prior art where in order to establish and to maintain the conformity between the substrates and the thermal interface material, they must be kept under constant pressures of up to 500 psi. Without the maintenance of such applied pressures, the prior art materials will not conform, causing air gaps to be established reducing the uniform thermal transfer and leading to hot spots and overheating of the heat source.

Preferably, the thermally conductive material has a polymeric binder that is a pressure sensitive adhesive, such as an acrylic or silicone pressure sensitive adhesive. The pressure sensitive thermally conductive material allows for bonding of the thermal interface material directly to the adjacent surfaces of the heat source and heat sink without the need for other retaining means such as screws, rivets, clamps, etc. It also allows for the use of thermal interface materials on electronic components which previously could not retain such materials, due to size, configuration, etc. Moreover, it allows for the automated application and assembly of thermally conductive electronic assemblies or packages.

It is an object of the present invention to provide thermally conductive materials comprising a blend of a polymeric binder and a thermally conductive filler wherein the material has an expanded metal mesh layer embedded therein.

A further object of the present invention is to provide a thermally conductive, form stable sheet formed of a blend of a polymeric binder selected from the group consisting of acrylic resin, silicone rubber, fluorosilicone rubber, thermoplastic rubber and polyurethane, a thermally conductive filler and an expanded metal mesh which is embedded within at least one major surface of the material.

Another object of the present invention is to provide a thermally conductive interface comprised of a pressure sensitive adhesive polymeric binder and one or more thermally conductive fillers and an expanded metal mesh layer embedded within at least one surface of the interface.

IN THE DRAWINGS

Figure 1 shows a crosssectional as view of first preferred embodiment of the thermally conductive material of the present invention.

Figure 2 shows a crosssectional view of another preferred embodiment of the thermally conductive material of the present invention.

Figure 3 shows a crosssectional view of the embodiment of Figure 2 interposed between a heat source and a heat sink.

DETAILED DESCRIPTION OF THE INVENTION

A preferred embodiment of the present invention comprises a form stable, sheet like thermally conductive material formed of a polymeric binder, one or more thermally conductive fillers and an expanded metal mesh layer embedded into at least one major surface of the material. Such a device is shown in Figure 1.

In this embodiment, it is preferred that the first major surface 3 of the material be adjacent to the heat dissipator, such as a heat sink and the second major surface 4 is adjacent to heat source.

Figure 2 shows an alternative embodiment of the thermally conductive material wherein the expanded metal mesh 22 is fully embedded between the two major surfaces 24, 25 of the interface material.

As shown in Figure 2, the embodiment basically forms three layers or zones, with the two outer ones, 21, 23, being formed solely of resin and filler and the other 22, being formed of resin, filler and the expanded metal mesh.

Another preferred embodiment of the present invention is an assembly of a thermal energy generating means, such as an electronic component, a thermal energy dissipating means, such as a heat sink or a heat spreader, and a thermal energy transferring means such as a thermally conductive polymeric material interposed between the generating means and the dissipating means so as to move the thermal energy from the generating means to the dissipating means. Such an assembly is shown in Figure 3.

The assembly of Figure 3 shows the heat generating means, 35, which is typically an electronic component such as a semiconductor, a thermal energy transferring means formed of the embodiment of Figure 2 with two outer layers, 32, 34, being comprised of resin and filler and the inner or middle layer, 33, being comprised of the expanded metal mesh with the resin/filler matrix being embedded in the interstices of the metal mesh. A thermal energy dissipating means 31 is mounted to the outer surface of the outer layer of the transferring means.

As can be seen from Figure 3, the dissipating means, 31, in this instance a heat sink, has a disconformity or high spot 36 which applies pressure to the transfer means below and distorts the expanded metal mesh accordingly at 37. The expanded metal mesh accommodates such imperfections and allows the transfer means to conform to the surface of the heat sink so as to provide for uniform and constant thermal transfer across the entire surface of the substrate. This eliminates the potential for the generation of hot spots or the incomplete transfer of thermal energy from the heat generating means 35 to the heat dissipating means 31.

The thermally conductive material may be selected from a variety of well-known polymer binders, such as acrylic resin, silicone and fluorosilicone rubber, the thermoplastic rubber such as KRATON® rubber, and various polyurethanes filled with one or more thermally conductive fillers. Such materials formed of silicone thermoplastic rubber or urethane are taught in U.S. Patents 4,574,879, U.S. 4,869,954 and which are incorporated herein by reference in their entireties.

Preferably, the thermally conductive material is formed of a polymeric binder of a pressure sensitive adhesive material, such as silicone or an acrylic adhesive, one or more thermally conductive fillers and the expanded metal mesh layer. Such polymeric binders are well-known and commercially available. The preferred embodiment is a pressure sensitive acrylic adhesive, which are well-known and commercially available and is taught by U.S. Patent 5,213,868, which is incorporated herein by reference in its entirety. Thermally conductive fillers suitable for use in the present invention are particulate solids capable of providing the material with the desired thermal conductivity. Preferably, these fillers are particulate solids which are electrically insulative as well as thermally conductive.

Examples of such particles include but are not limited to aluminum oxide, aluminum nitride, boron nitride, magnesium oxide, zinc oxide, silver, gold and copper or metal coated materials, such as silver coated copper or silver coated aluminum.

The particles should be of a sufficiently small size as to not distort the surface of the thermally conductive material. Preferably the filler will be of a size from about 1 micron to about 100 microns, more preferably in a range of from about 5 microns to about 25 microns. The fillers are to be included in the binder in an amount sufficient to provide the desired thermal conductivity. Preferably, the fillers are included in amount of from about 10% by weight to about 85% by weight of the finished product. More preferably, the fillers are included in amounts ranging from about 40% by weight to about 75% by weight and most preferably about 68% by weight. The more preferred fillers are boron nitride, magnesium oxide and aluminum oxide with boron nitride being the most preferred filler.

Additional ingredients may also be added so long as they do not interfere with the conformability or thermal conductivity of the product. For example, it is preferred to use a solvent when compounding the binder or a coupling agent for the filler so as to make the mixing and application easier. If desired, one may also add a pigment, flame retardant, and/or antioxidant to the material.

Examples of preferred metals useful as an expanded metal mesh, include but are not limited to, aluminum, copper, silver, iron, tinned copper, nickel plated copper, tin plated, copper clad steel and other plated or clad metals. Regardless of the material used, it should be as thin as practicable while still providing the desired conformability. Such materials are well known and commercially available. Typically these meshes are thin, about .005 inch (.127 mm) .030 inch (.76mm) in thickness and generally have diamond shaped openings of from about 25 openings/inch^2 to 2600 opening/inch^2. Such products are available from a number of commercial sources, including Exmet and Delker.

The expended metal mesh may be totally embedded in the thermally conductive material or at least partially embedded into one surface of the thermally conductive material. Preferably, the thermally conductive material is formed such that there are three or more layers or zones with the expanded metal mesh/conductive resin layer forming the center layer and solely thermally conductive material forming the outer layers.

When the thermally conductive material of the present invention is formed as the pressure sensitive material it may be formed as a continuous tape, a tape containing discrete parts or as individual pads or pieces.

The thermally conductive material of the present invention may be formed in many ways.

One method of forming the material is to combine the resin binder with the selected filler or fillers and thoroughly mix the ingredients while slowly adding a solvent until a liquid having a smooth texture is achieved. The material is then cast onto a release sheet such as a piece of glass, MYLAR® film or coated paper, containing the expanded metal layer and heated to drive off the solvent and form the thermally conductive material.

An alternative method is to thoroughly mix the ingredients together with a sufficient amount of solvent to obtain a thin liquid. The liquid can then be sprayed or coated onto a surface of the expanded metal mesh and heated to cure. Alternatively, the same liquid formulation may be used as a clip both into which the metal mesh is dipped to form the desired material.

Another method of forming the heat conductive material of the present invention is by molding. This is particularly useful when one wishes to form a substantially thick heat conductive layer or when one wishes to form a specifically shaped heat conductive material. In molding the heat conductive material, the components are mixed and poured into a prefabricated mold which contains the expanded metal mesh in its desired position. Preferably, one may coat the inside of the mold with a release coating before adding the components. The mold is then heated or otherwise subjected to an external energy field to form the molded shape. Instead of using a separate mold, it may be desired to use a mold which allows the heat conductive material to be molded in place directly to one of the surfaces it will contact.

A preferred method is to form a laminated pressure sensitive adhesive material of three or more layers in which the center layer is formed of the expanded metal mesh, impregnated with the conductive resin matrix and an outer layer of the thermally conductive material formed on each side of the metal layer to form a cohesive laminated material. The outer layers may occur sequentially so that one side of the mesh layer is impregnated and cured and then the process is repeated on the opposite side. Preferably, the process is applied to both sides simultaneously. When the material is adhesive, the outer surfaces are covered by a release layer such as a coated paper, foil or a plastic film.

The thermally conductive product may be formed into continuous or discontinuous tapes; or sheets or pads and then cut to the desired shape; or molded in the desired shape at the outset, either in a mold or directly in place, as described above. If desired, one or both major surfaces may contain additional air removing structures, such as embossments or throughhholes as are described in U.S. Patent 5,213,868, which has been incorporated herein in its entirety.

The resultant thermally conductive material should be sufficiently soft so as to conform to the surfaces with which it interfaces. Preferably, the material should have a Shore A hardness of less than 90, more preferably, a Shore A hardness of about 10.

The properties exhibited by a typical product prepared in accordance with the present invention are as follows:

Thickness-1 to 20 mils, preferably about 5-8 mils.

Hardness, Shore A-10 to 90 (ASTM D-2240)

Thermal Impedence-0.10° to 1.00°C./W (Chomerics No. 27).

Thermal Conductivity-0.5 - 2 W/m-K (Chomerics No. 28).

While this invention has been described with references to its preferred embodiments, other embodiments can achieve the same result. Variations and modifications of the present invention will be obvious to those skilled in the art and it is intended to cover in the appended claims all such modifications and equivalents as fall within the true spirit and scope of this invention.

CLAIMS:

1.) An electrical assembly comprising a means for dissipating thermal energy, an electronic component which generates thermal energy and a means for transferring thermal energy from the electronic component to the means for dissipating thermal energy interposed between the means for dissipating thermal energy and the electronic component and wherein the means for transferring thermal energy is composed of a sheet formed of a polymeric binder, thermally conductive filler distributed throughout the binder and an expanded metal mesh layer at least partially embedded with a major surface of the sheet.

2.) The electrical assembly of Claim 1 wherein the means for dissipating thermal energy is selected from the group consisting of heat sinks and heat spreaders.

3.) The assembly of Claim 1 wherein the electronic component is selected from the group consisting of semiconductors, transformers, DC to DC converters, multichip modules, and electronic subassemblies.

4.) The assembly of Claim 1 wherein the means for transferring thermal energy has an air removing device selected from the group consisting of embossments and throughholes formed in at least one surface.

5.) A thermally conductive material comprising a form stable sheet formed of a polymeric binder, a thermally conductive filler and an expanded metal mesh layer at least partially embedded into one major surface of the material.

6.) A thermally conductive material comprising a form stable sheet formed of a blend of a polymeric binder selected from the group consisting of acrylic resin, silicone rubber, fluorosilicone rubber, thermoplastic rubber and polyurethane, one or more thermally conductive fillers and an expanded metal mesh at least partially embedded into one major surface of the material.

7.) A thermally conductive material comprising a form stable sheet formed of a polymeric binder, a thermally conductive filler, and an expanded metal mesh layer completely embedded within the sheet.

8.) The thermally conductive material of Claim 7 wherein the binder is a pressure sensitive acrylic resin and the one or more thermally conductive fillers are selected from the group consisting of aluminum oxide, boron nitride, magnesium oxide, zinc oxide, and mixtures thereof.

9.) The thermally conductive material of Claim 7 wherein the expanded metal mesh is positioned centrally in the polymeric binder.

10.) A thermally conductive interface comprising a first layer of thermally conductive resin formed of a resin and a thermally conductive filler distributed throughout the resin, an expanded metal mesh layer overlaying the first layer and embedded at least partially therein, a second layer of thermally conductive resin formed of a resin and a thermally conductive filler distributed throughout the resin, the second layer, overlaying and being partially embedded into the expanded metal mesh layer.

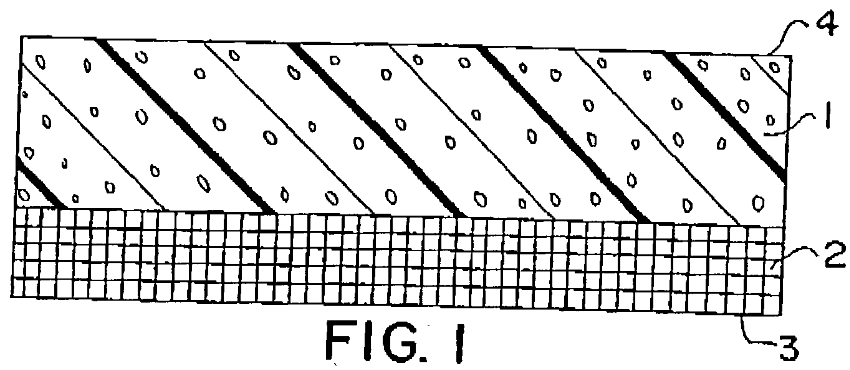

FIG. 1

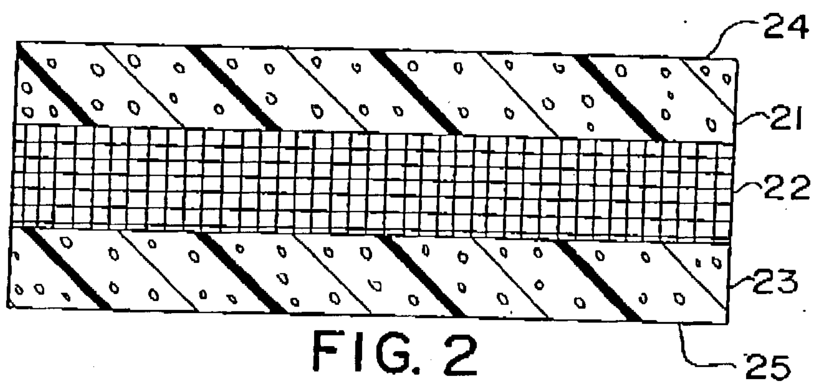

FIG. 2

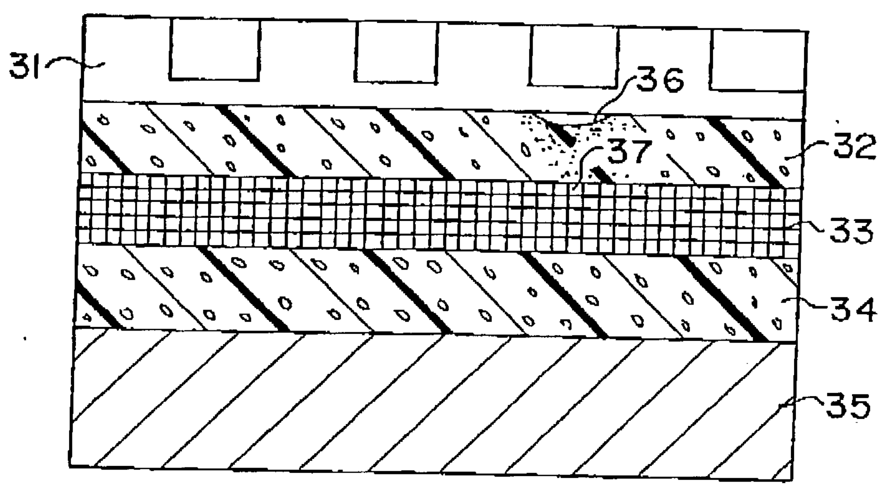

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/07793

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :B32B 3/24; H05K 7/00; F28F 7/00
US CL :428/138; 361/709
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 428/138, 135, 247, 256, 323, 913; 361/709, 713; 174/16.3; 165/185

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS: U.S. Text-File Expanded (5A) Metal (5A) Mesh (P) Gasket#

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,869,954 (SQUITIERI) 26 September 1989, column 5, lines 15-20.	1-10
Y	US, A, 4,900,877 (DUBROW) 13 February 1990, column 5, lines 35-40.	1-10

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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